NDIA System Engineering Division

Integrated Diagnostics Committee

Electronics Prognostics Technology

Task Group

Outbrief

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Foster-Miller Inc.

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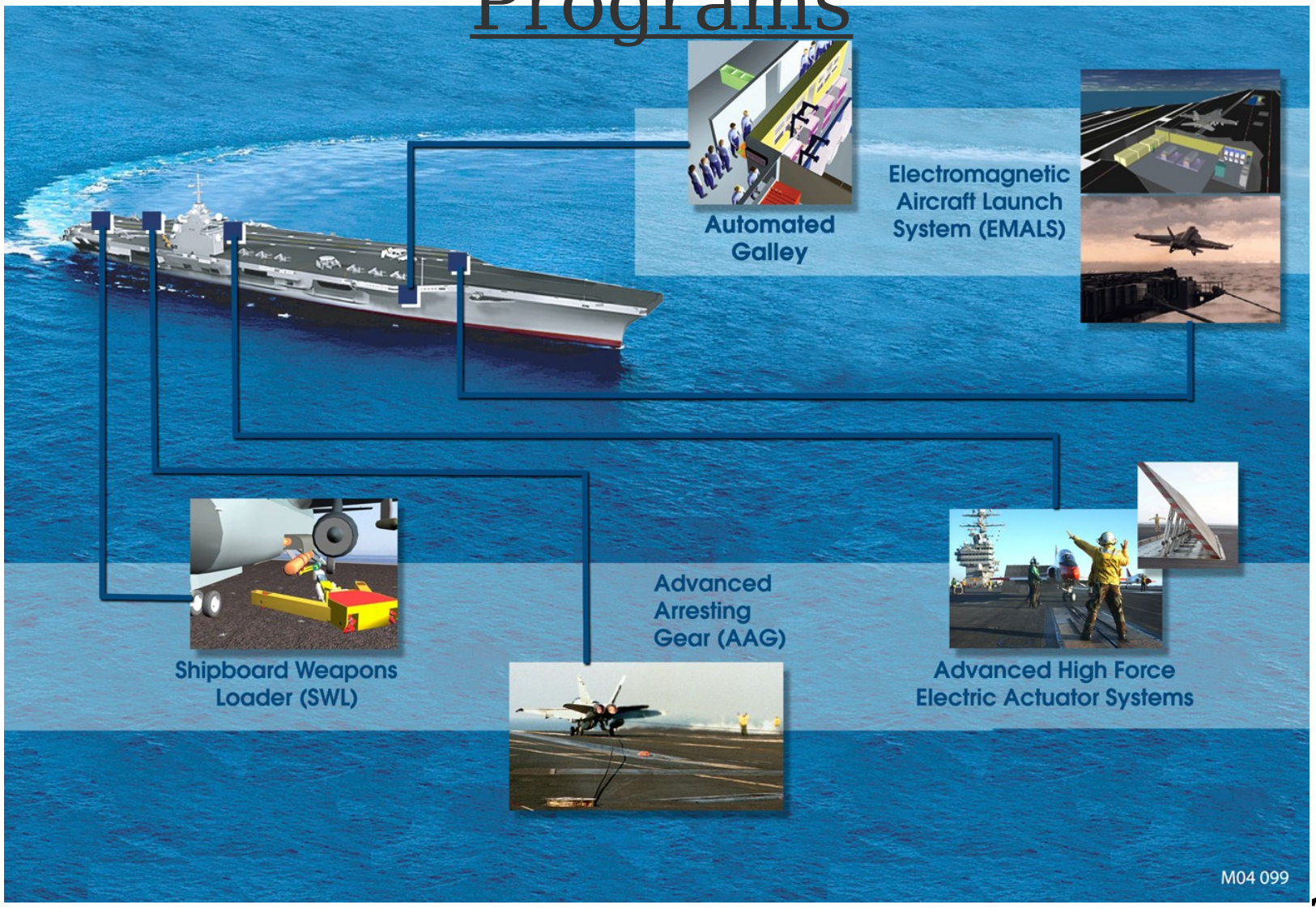
Key FMI EES System Programs



Electronics Prognostics Task Group

NDIA Integrated Diagnostics Committee

Electronics Prognostics Task Management IPT

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DOD IPT

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Electronics Prognostics Workshop Process Overview

Day 1 – DOD IPT Reports

- **Define needs by weapon system and application**
- **Assemble needs onto template**
  - **Prognostic need**
  - **Weapons system and application**
  - **Program elements to address need**
  - **Needs and development program timeline**

Day 2 – DOD and Industry

- **Integrate templates by application type**
- **Formulate template elements into activities:**
  - **S&T**
  - **RDT&E**
  - **V&V**
- **Translate template elements to roadmap**
- **Draft final report key points and recommendations**

Electronics Prognostics Logistics, Readiness, and Systems Engineering Key Points

- There is a greater reliance on sophisticated electronics and electrical based systems:
  - Navy – JSF, EMALS, AAG, Shipboard Weapons Loader, shipboard electric drive, Integrated Fight Through Power, ForceNet, linear motor elevators, etc.
  - Army – FCS Hybrid electric drive, soldier mounted electronics, MTRS, Net Centric Warfare, etc.
  - AF – JSF, Predator, Global Hawk, ABL, etc.
- Electronic Prognostics increases weapons system availability with fewer maintainers:
  - Prognostics provides advanced warning of deterioration as opposed to reporting failure
  - Reduces downtime for unscheduled maintenance and reduce costly secondary damage associated with failures
  - Supports distance support (reach back) initiatives
  - Required technology to enable performance based and sense and respond logistics

Investment Is Required To Develop The Technology Foundation For Electronics Prognostics

Key Development and Fielding Issues for Electronic System Prognostics

- Current technology will not support fielding Electronics Prognostics as part of either legacy or new weapon systems.
- Engineering and economic benefits of electronic prognostic technology cross-fertilization between programs are not happening.
- Systems Engineering Processes for designing Electronics Prognostics technology into new weapon systems or spiral development in legacy weapon systems are not currently in place.
- Integration of Electronics Prognostics technology into the emerging support processes is essential.

• A coordinated program is required, with funding, to develop, validate, and integrate Electronic Prognostics within a Systems Engineering environment.

Key Task Findings for Electronics Prognostics Systems Engineering

- **There is a greater need to predict when an operational capability will be lost than there is to predict an electronic component or subsystem failure.**
- **Needed technology spans the spectrum from "low hanging fruit" to technology requiring invention.**
- **Current R&D and SBIR technology can be transitioned to a program if focused and funded.**
- **Commercial technologies exist that could become a baseline for DOD systems, but adaptation to the differences in operating environment for DOD versus commercial applications must be addressed.**

RDT&E is required to develop Electronics Prognostics Technology.

E-PROG TASK GROUP RDT&E PROGRAM ROADMAP

Man Year Summary By FY

	FY1	FY2	FY3	FY4	FY5	FY6	FY7	FY8	Total
6.1 Total	41	45	26						112
6.2 Total	28	48	112	80	32				300
6.3 Total	0	20	20	72	88	60	8		268
6.4 Total	0	0	8	16	20	44	44	8	140
Totals	69	113	166	168	140	104	52	8	820

- **Nearly 70% of Program is 6.2 & 6.3 - only 14% of Program is 6.1**
- **Benefits of effort start to be realized in FY3**
- **Majority of effort is completed within 4 – 5 years**

E-PROG TASK GROUP R&D PROGRAM ROADMAP

Breakout by R&D Category and Product Type

E-Prog Description	6.1 Basic Research	6.2 Applied Research	6.3 Tech Demo	6.4 Tech Application	Prod. Type
1. Physics of Failure Model for Gates, Devices and IC's					M
2. Electronics Prognostics for High Power Switching Electronics					PT
3. BIP Prognostics for Devices and Circuit Boards					PT
4. Electronics/electro-optical Prognostics for Tactical Sensor Systems					PT
5. Generic Environmental/Operational Parameter Monitoring Module for Electronic Prognostics					H
6. Electronic Prognostics for C4ISR Systems					PT
7. Maintenance Mode/Prognostic Interaction Design Tool					T
8. Interconnection Prognostic Technology					PT
9. Electronic Interconnection Prognostic Design Tools					T
10. Electronics Prognostics Financial Modeling Tool					T
11. Tool for Logistics Impact of E-Prog					T
12. Prognostics for HCI Electronics/Electro-Optics					PT
13. Prognostics for Redundant Electronic Systems					PT
14. Electronic Prognostics Design Tool for Environmentally Tolerant Electronics					T
15. Electronics Life Usage Assessment and Prognostics - Electronic Prognostics Life Usage System (E-Plus)					PT
16. Data Enterprise System - Module to LRU Tracking for Electronics Prognostics					PT
17. Electronic Prognostics Reasoner Engine applicable to Device through System					PT
18. Electronic System Level Prognostic and RUL Tool Set					T
19. Prognostics for Power Supplies and Converters					PT

M = Model, H = Hardware, PT = Prognostic Technology, T = Tool

ELECTRONICS PROGNOSTICS RDT&E PROGRAM EXAMPLE

Generic Environmental/Operational Parameter Monitoring Module for Electronic Prognostics

Program Rationale: This program area addresses the need for a hardware device to monitor the operational environment affecting life usage of electronic devices, circuit boards and systems. Sensed parameters, sensor performance characteristics, sensor configuration (built into or added on to the device), data analysis algorithms, degree of smart sensing are all a part of this module. The methodology for verification and validation of this module form part of this task.

Key Program Elements:
- Operational regime (vibration, humidity, chemical environment, voltage transients, etc.)
- Virtual and conventional sensor technology and algorithm development
- Product: Generic operational parameter sensing and RUL predictor including software and/or hardware
- Module to be composed of interoperable building blocks
- Reconfigurable
- Prognostics and BIT for the module
- Built-in calibration
- Open system/modular architecture for 4 locations
- Flight-ready hardware/software (system) (not orange)
- Minimum new sensor count

Horizon (module): T = 300 hr
O = 3000 hr

Confidence (module): T = 85%
O = 95%

S & T Category	Estimated Duration (Years)	Budgetary Man-Years
6.1 Basic Research	0	0
6.2 Applied Research	1	8
6.3 Advanced Technology Development	2	24
6.4 Advanced Component Development	1	16
Total	4	48

Table 6. E-PROG Program 5 Development Plan

Why a DoD Initiative?

- True multi service issue
- Time frame appropriate to impact a number of advanced systems - CVN-21, DDX, FCS, JSF
- Fits in with reduced manning and reduced maintenance costs funding availability for military
- Potential to provide significant benefits to advanced military systems
  - Total cost of ownership reduction
  - Reduction of cost of false removals
  - Improved system availability

Next Steps

- **Final report published by NDIA Systems Engineering Division**
- **Electronic Prognostics task results briefings - Ongoing**
- **Recommend DoD develop Electronics Prognostics S&T Program Execution Plan Including Acquisition Plan**

Backups

Legacy VS JSF PHM
CY 00 CBA Summary of Expectations

	PHM Benefits
Maintainability	
MFHB CND	79-82% Improvement
MFHBME	13-14% Improvement
MFHBR	3% Improvement
MMH/FH	17-32% Reduction of 6-10%
Support Equipment	
QTY	
Weight (Lbs.)	
Volume (cu ft)	
Manpower	
QTY	Reduction of 46-52%
Logistics Footprint	
C17 Loads, Tons	Reduction of 2-17%
Safety	
Mishap Reduction	Reduction of 14-38
SGR	
SGR (Initial/Sustained)	10 to 14% Improvement
Airframe/OML Restoration	
Recurring Cost	$1.05B - $7.87B Cost Avoidance

E-Prog Workshop I Background

JSF Assigned Task (Andy Hess, John Kelly)

- **Define diagnostics data needed to implement electronics prognostics**

Conclusions:

- **The need for electronic system prognostic capability is prominent in many new weapon systems relevant to all services.**
- **Electronic System prognostics cannot be fielded now. … Additional S&T, R&D and V&V efforts are needed.**

Recommended Follow-on Actions:

- **Define and prioritize the S&T, R&D and V&V tasks required to establish a fieldable electronic system prognostic capability..**
- **Generate a program roadmap for planning, sequencing and funding these tasks. Establish funding sources, transition paths and sponsors and implement the Electronic System Prognostic - Implementation Initiative (ESP-I^2).**

NAVAIR Pax River, MD - Rotary Wing

Program 12
Prognostics for HCI Electronics/Electro-optics

Application: Glass cockpit (HCI), flat panel (8x10 displays)
- Sensor/processors/algorithms and V&V of HCI
- Conversion to actionable maintenance information (AMI)

Characteristics of anticipated product:
Horizon: (MLDT Based) T = 20 hours
O = 100 hours

Confidence*:* T = 85%
O = 90%

Program 13
Prognostics for Redundant Electronic Systems

Application: All redundant type aircraft flight control systems
- Sensor/processors/algorithms and V&V
- Prognostics for redundant channels & conversion to AMI

Characteristics of anticipated product:
Horizon: T = 300 hours
O = 300 hours

Confidence*:* T = 85%
O = 95%

Program 7
Maintenance Mode/Prognostics Interaction Design Tool

Application: Tool for Electronic/electromechanical Systems
- 2-way tool: maintenance impact on prognostic design and prognostic performance impact on maintenance mode.

Characteristics of anticipated product:
- Trade space to be defined

Horizon: N/A
Confidence*:* N/A

Program 8
Interconnection Prognostics Design Tools

Application: All wiring and optical harnesses and connectors.
- Sensor/processors/algorithms with built in V&V
- Predictive results integration algorithm /conversion to AMI

Characteristics of anticipated product:
Unit Horizon: T = 300 hours
O = 300hours

Unit Confidence*:* T = 85%
O = 95%

E-PROG R&D PROGRAM MAN YEAR SUMMARY BY R&D CATEGORY

E-Prog Program Product Type	6.1 Content (Man-Years)	6.2 Content (Man-Years)	6.3 Content (Man-Years)	6.4 Content (Man-Years)	Total (Man-Years)
Tools	20	76	72	40	208
Electronics Prognostics Technology	60	184	172	84	500
Models	32	32	0	0	64
Hardware		8	24	16	48
Totals	112	300	268	140	820

E-PROG R&D PROGRAM EXAMPLE 1

Electronic Prognostics Reasoner Engine applicable to Device through System

Program Rationale: This program area addresses the need for a generic modular prognostic engine to enable the operation of electronics prognostic systems and their design and evaluation tools and models. The engine must support the prediction of Remaining Useful Life (RUL) of electronic circuit boards, LRUs, and systems. The end product is a software engine. The capability to author and support the development of sensed parameters, sensor performance characteristics, sensor configuration (built into or added on to the device), data analysis algorithms and degree of smart sensing all form a part of this product. The formulation and validation of the decision methodology for predicting RUL up to the system level and the relation to fault characteristics at the device, circuit, circuit board level and LRU is a second and equally important task of this program area.
The Verification and Validation of the prognostic engine are included as part of this program.

Key Program Elements:

- Module through system
- Electronic Systems Prognostics Engine is the reasoner that goes with tool sets
- Built-in V&V.
  - Enables development of RUL prediction, horizon, delta horizon, and confidence cone algorithms.
- Robust, open architecture, learning, upgradeable

Must at least support tools and models used for designing systems having:

Horizon: T = 50 hours
O = 200 hours

Confidence: T = 85%
O = 95%

S & T Category	Estimated Duration (Years)	Budgetary Man-Years
6.1 Basic Research	2	12
6.2 Applied Research	1	20
6.3 Advanced Technology Development	1	20
6.4 Advanced Component Development	1	8
Total	5	60

Table 18. E-PROG Program 17 Development Plan

E-PROG R&D PROGRAM EXAMPLE 2

Electronics Prognostics Financial Modeling Tool

Program Rationale: This program area addresses the need for a prognostic design financial evaluation tool applicable to all electronic prognostic system designs. The intent is to enable the cost benefit evaluation and comparison of candidate electronic prognostics design approaches. The modeling tool should also support prognostic design financial evaluation of the full functional system including the interconnections between the elements and subsystems. The Verification and Validation of the prognostic financial modeling tool are included as part of this program.

Key Program Elements:

- Investment analysis
- ROI
- Net Present Value of competing prognostic design approaches
- Savings cash flow
- System to module cost benefit analysis
- Analysis of Alternatives (AoA)
- Open source software tool
- Built-in V&V

Horizon: N/A
Confidence: N/A

S & T Category	Estimated Duration (Years)	Budgetary Man-Years
6.1 Basic Research	0	0
6.2 Applied Research	1	4
6.3 Advanced Technology Development	2	4
6.4 Advanced Component Development	1	4
Total	4	12

Table 11. E-PROG Program 10 Development Plan

E-PROG R&D PROGRAM EXAMPLE 3

Interconnection Prognostic Technology

Program Rationale: This program area addresses the need for prognostics for all forms of interconnection of electronic and electromechanical systems. The intent is to enable prognostics for the full functional system including the interconnections between the elements and subsystems. Electrical, optical and wireless interconnects are included. Sensed parameters, sensor performance characteristics, sensor configuration (built into or added on to the device), data analysis algorithms, degree of smart sensing and integration with electronic and electromechanical prognostic technologies are all a part of this effort. The Verification and Validation of the prognostic technology are included as part of this program.

Key Program Elements:

- Interconnection degradation prognostics for wire harnesses and connectors
- Interconnection fiber degradation prognostics for optical harnesses and connectors.
- Prognostic technology for wireless interconnections.
- Sensor/processors/algorithms
- Predictive results integration algorithm
- Conversion to actionable maintenance information

Horizon: T = 300 hr
O = 300 hr

Confidence: T = 85%
O = 95%

S & T Category	Estimated Duration (Years)	Budgetary Man-Years
6.1 Basic Research	1	4
6.2 Applied Research	2	20
6.3 Advanced Technology Development	2	16
6.4 Advanced Component Development	1	8
Total	6	48

Table 9. E-PROG Program 8 Development Plan

E-PROG R&D PROGRAM TASK GROUP ROADMAP